

Burning following tree fall causes local elimination of annual sorghum

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Annual sorghum (*Sorghum* spp) is a dominant feature of the monsoonal tallgrass savannas of northwestern Australia. Its prolific seeding makes it a key resource for granivores (Andrew 1986; Woinarski & Tidemann 1991; Dostine *et al.* 2001), and its dominant biomass has a major influence on grass-layer dynamics and tree-grass interactions. In particular, the high biomass and early curing of annual sorghum make it a fundamental driver of the very high fire frequencies that are characteristic of these ecosystems (Andersen 1996; Cook *et al.* 1998; Russell-Smith *et al.* 2003).

Annual sorghum has a peculiar life history in that its seed bank is transient. Seed falls at the end of the wet season (March/April), undergoes a relatively brief period of dormancy and germinates following the first significant rains of the following wet season (Andrew & Mott 1983; Mott & Andrew 1985). Such a life history is successful because of the near-certain absence of significant rain events during the dry season, and the consequent likelihood of follow-up rain subsequent to germination early in the wet season, combined with seed set occurring before the earliest possible cessation of the wet season. However, it is also risky, because failure of a seed crop leads to elimination of the population (Smith 1960). This risk is exploited by fire managers wishing to reduce fuel loads, by burning annual sorghum populations in the wet season following germination but before seed set (Lane 1996).

Fire poses another potential risk to populations of annual sorghum through the burning of fallen seed. Given the high likelihood of fire over the dry season, protection from fire through seed burial in the soil is a key requirement for population persistence. The seeds of annual sorghum are relatively large (~12 mg, not including the awn), so they can potentially escape high intensity fire by germinating from relatively deep in the soil (Bond *et al.* 1999). To promote burial, the seeds possess long, hygroscopic awns that drill the seed into the soil following seed fall (Andrew & Mott 1983). Despite this, most seeds are buried less than 2 cm even in sandy soils (Andrew & Mott 1983), and significant seed mortality can occur during fire (Mott & Andrew 1985), with modelling suggesting that this can limit population size

(Watkinson *et al.* 1989; Cook *et al.* 1998). However, high density of annual sorghum readily persists under high fire frequency.

Rather than a threat, fire is considered a promoter of annual sorghum abundance by maintaining the open canopy conditions required for seedling establishment and by reducing competition with other grass-layer species (Cook *et al.* 1998). Indeed, the current landscape dominance by annual sorghum is seen by some as an artefact of the increased frequency and extent of high intensity, late season wildfires following the breakdown of Aboriginal fire management (Yibarbuk *et al.* 2001; Russell-Smith *et al.* 2003; Bowman *et al.* 2007).

Here we describe an unusual situation where fire has led to the local elimination of annual sorghum. This has occurred at a location immediately adjacent to the Mary River Ranger Station in southern Kakadu National Park, where a 'freak' tornado cut a swathe of destruction approximately 3000 x 800 m in area in early March 2007 (Figure 1). When we visited the site in March 2008, the core affected area had a dense grass-layer dominated by annual sorghum (Figure 2). The species-level taxonomy of annual sorghum is contentious (Spangler 2003). Our study species is a distinct taxon characterised by drooping infructescences and extremely long awns that is restricted to the sandstone hills of the southern Kakadu region (Kym Brennan, pers. comm). Its density in the tornado-affected area was far higher than under the canopy of adjacent, intact vegetation, as reflects the broader preference of annual sorghum for canopy gaps (Cook *et al.* 1998; Scott 2007). However, there were numerous gaps in annual sorghum cover within the tornado-affected area, where fallen trees had burnt during the 2007 dry season. Some of these gaps were linear and associated with burnt logs (Figure 3), whereas others were far more extensive and associated with the burning of spreading branches (Figure 4). It was clear that the gaps were related to burning rather than directly to tree fall, as annual sorghum occurred in association with fallen trees that had not been burned (Figure 5). Although annual sorghum density was lower in such areas, this can be explained by reduced local seed production due to the direct damage to annual sorghum caused by tree fall (the tornado occurred before seed set).

The most likely explanation for the annual sorghum gaps is that the burning of fallen trees destroyed the sorghum seed bank. The soil at the site is sandy, so that seeds were likely to have been effectively buried. One possibility is that the fuel conditions associated with fallen trees resulted in unusually high fire intensity. The site was burned in May 2007, and although fire intensity was generally low (Rob Muller, pers. comm.) the extra fuel created by fallen branches might have resulted in localised areas of high fire intensity. However, high fire intensity seems to be an unlikely explanation given that annual sorghum readily persists under the highest intensity fires known in native grass-layers of Australian tropical savannas (Andersen *et al.* 2003). A more likely explanation is that the seed bank was affected by unusually long fire residence times associated with the burning of woody debris. The impact of fire on soil biology is determined by the extent and duration of soil heating, which is not simply related to

fire intensity (Alexander 1982). In particular, smouldering combustion is known to produce long heating duration times leading to lethal temperatures near the soil surface (Hartford & Frandsen 1992). We hypothesize that high fire residence times associated with the burning of fallen trunks and branches, possibly relating to smouldering combustion, has led to sub-surface soil temperatures at the tornado site that are lethal to annual sorghum seeds.



Figure 1. Tornado damage one week after the event in March 2007. (Alan Andersen)



Figure 2. Tornado damage one year after the event in March 2008, showing dominance of the grass layer by annual sorghum. (Alan Andersen)



Figure 3. Linear gap associated with a burnt log. (Alan Andersen)



Figure 4 (a,b). Extensive gaps associated with spreading branches. (Alan Andersen)



Figure 5. Annual sorghum associated with fallen branches that have not been burnt. (Alan Andersen)

It is interesting to note that the annual sorghum gaps were often almost completely bare (Figures 3, 4b), which indicates that other herbaceous species were similarly affected by high fire residence times. However, in some cases the gaps had a high cover of forbs such as *Commelina* sp. Sandstone (R.J.Fensham 739, NT Herbarium) (Figure 4a) and species of *Spermacoce*, which indicates that these species were not as sensitive as annual sorghum to high fire residence times. Such reduced sensitivity may be due to deeper seed burial or to greater tolerance of high temperatures. It is unclear if such patchy forb cover was related to local variation in fire residence times or to variation in soil seed banks.

To our knowledge, such an observation of localised elimination of an annual sorghum population by fire has never previously been reported. Given the frequent and widespread damage caused by cyclones across sub-coastal northern Australia (Cook & Goyens 2008), such fire-induced gaps in annual sorghum are likely to be very common. However, their longer term implications for grass-layer dynamics are unclear. The seeds of annual sorghum are poorly dispersed (with maximum dispersal distances of about 2.5 m; Andrew & Mott 1983), so that although the gaps are relatively small it might take several years for them to be completely recolonised from surrounding areas (see Lane 1996). There will be a persistent legacy if the absence of annual sorghum allows for the establishment or expansion of other grass-layer species (such as species of *Commelina* and *Spermacoce*) that then limits sorghum re-colonisation.

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References

- Alexander M.E. (1982) Calculating and interpreting forest fire intensities. *Canadian Journal of Botany* 60, 349-357.
- Andersen A.N. (1996) Fire ecology and management. In *Landscape and Vegetation Ecology of the Kakadu Region, Northern Australia* (eds C.M. Finlayson and I. Von Oertzen), pp. 179-195. Kluwer Academic Publishers, Amsterdam.
- Andersen A.N., Cook G.D. and Williams R.J. (2003) *Fire in Tropical Savannas: the Kapalga Experiment*. Springer, New York.
- Andrew M.H. (1986) Granivory of the annual grass *Sorghum intrans* by the harvester ant *Meranoplus* sp. in tropical Australia. *Biotropica* 18, 344-349.
- Andrew M.H. and Mott J.J. (1983) Annuals with transient seed banks: the population biology of indigenous *Sorghum* species of tropical north-west Australia. *Australian Journal of Ecology* 8, 265-276.
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- Bond W.J., Honig M. and Maze K.E. (1999) Seed size and seedling emergence: an allometric relationship and some ecological implications. *Oecologia* 120, 122-136.
- Bowman D.M.J.S., Franklin D.C., Price O.F. and Brook B.W. (2007) Land management affects grass biomass in the *Eucalyptus tetrodonta* savannas of monsoonal Australia. *Austral Ecology* 32, 446-452.
- Cook G.D. and Goyens C.M.A.C. (2008) The impact of wind on trees in Australian tropical savannas: lessons from Cyclone Monica. *Austral Ecology* 33, 462-470.
- Cook G.D., Ronce O. and Williams R.J. (1998) Suppress thy neighbour: The paradox of a successful grass that is highly flammable, but harmed by fire. In: Proceedings of the 13th Conference on Fire and Forest Meteorology, Lorne, 71-74.
- Dostine P.L., Johnson G.C., Franklin D.C. and Hempel C. (2001). Seasonal use of savanna landscapes by the Gouldian finch, *Erythrura gouldiae*, and co-existing finches in the Yinberrie Hills area, Northern Territory. *Wildlife Research* 28, 445-458.
- Hartford R.A. and Frandsen W.H. (1992) When it's hot, it's hot ... or maybe it's not! (Surface flaming may not portend extensive soil heating). *International Journal of Wildland Fire* 2, 139-144.
- Lane A. (1996) *Understorey vegetation interactions and the effect of wet season burning in a tropical savanna, Northern Territory*. Honours Thesis, Northern Territory University, Darwin.
- Mott J.J. and Andrew M.H. (1985) The effect of fire on the population dynamics of native grasses in tropical savannas of north-west Australia. *Proceedings of the Ecological Society of Australia* 13, 231-239.
- Russell-Smith J., Yates C., Edwards A., Allan G.E., Cook G.D., Cooke P., Craig R., Heath B. and Smith R. (2003) Contemporary fire regimes of northern Australia, 1997-2001: change since Aboriginal occupancy, challenges for sustainable management. *International Journal of Wildland Fire* 12, 283-297.
- Scott K.A. (2007) *The distribution and dynamics of grass-layer plants in a long-unburnt savanna*. PhD Thesis, Charles Darwin University, Darwin.
- Smith E.L. (1960) Effects of burning and clipping at various times during the wet season on tropical tall grass range in northern Australia. *Journal of Rangeland Management* 13, 197-203.
- Spangler R.E. (2003) Taxonomy of *Sarga*, *Sorghum* and *Vacoparis* (Poaceae: Andropogoneae). *Australian Systematic Botany* 16, 279-299.
- Watkinson A.R., Lonsdale W.M. and Andrew M.H. (1989) Modeling the population dynamics of an annual plant *Sorghum intrans* in the wet-dry tropics. *Journal of Ecology* 77, 162-181.
- Woinarski J.C.Z. and Tidemann S.C. (1991). The bird fauna of a deciduous woodland in the wet-dry tropics of northern Australia. *Wildlife Research* 18, 479-500.
- Yibarbuk F., Whitehead P.J., Russell-Smith J., Jackson D., Godjuwa C., Fisher A., Cooke P., Choquenot D. and Bowman D.M.J.S. (2001). Fire ecology and Aboriginal land management in central Arnhem Land, northern Australia: a tradition of ecosystem management. *Journal of Biogeography* 28, 325-343.